difficult to achieve an adequate SNR when trying to receive the neighboring base stations. More particularly, transmissions from the neighboring base stations will be jammed by the close-by base station—a classic near/far problem.

A power control system is necessary to solve the near/far problem for the mobile to base station communication link. As the mobile comes close to one base station, it reduces its transmitter power accordingly so as to achieve a just adequate Eb/No at the closest base station. This results in a lower Eb/No at the neighboring base stations, perhaps making it difficult to receive the mobile's signal at these locations. Thus, as a result of the power control system, neighboring base stations will typically have difficulty measuring mobile signal timing when a mobile unit is positioned near a close-by base station.

In the IS-95 CDMA system, the processing gain is nominally 21 dB. This is simply the ratio of the chip rate (1.2288 MHz) to the maximum data rate (9600 bps). At a point equidistant between two base stations, the transmitter power needed for both base stations is about the same. The resulting SNR at both base stations of the received mobile signal will likely be more than adequate to obtain good timing measurements. However, when the mobile station moves to a point closer to one base station than another, the transmitter power will be reduced. This will lower the received Eb/No at the further away base station. The measurement SNR can be raised by integrating over a longer time interval than a single bit time, effectively increasing the processing gain. For example, if the signal were to be integrated over one code repetition or 32768 chips, the SNR is improved by 24 dB compared to the SNR at 9600 bps because the processing gain becomes 45 dB (10* log 32768). If a 5 dB SNR is needed for good time tracking, then the signal at the far base station can be 30 dB weaker than the close base station. This SNR or better can be achieved in about 90% of the cell area, assuming 4th power propagation. Thus, in 90% of the system's coverage area, the base stations will be typically be capable of time difference measurements in support of positioning, provided that good base station geometry is available to obtain accurate positioning. The 10% of the cell area where time difference measurements between base stations is not available (with the above specified integration time) corresponds to the center of the cell area out to approximately 30% of the maximum cell radius. Thus, for base stations separated by 4 miles (2 mile cell radius) the radius of the area where positioning cannot be done with the above bandwidth assumptions is about 1000 meters.

It should be noted that there are limitations as to the time of integration that might be employed due to Doppler considerations. For example, if a mobile is traveling at 60 mph on a line between two base stations, the differential Doppler is about 2×10^{-7}. This amounts to about 170 Hz in the 800 MHz cellular band. This is sufficient Doppler to make integration over 32768 chips somewhat difficult. Thus, the above estimates should be taken as best case.

The basic method of mobile station receive only positioning is described above. In this method, the mobile must receive three or more cell pilot signals from three or more nearby base stations and calculate time differences of arrival of the pilot signals. These arrival time differences allow hyperbolic lines of position to be determined, with the mobile terminal's position being where these hyperbolic lines intersect. However, for the reasons explained above, when the mobile is too close to a base station to obtain an adequate SNR on the two farther away cells, the required signal arrival time differences cannot be easily measured, and therefore some other method must be utilized to determine the position of the mobile station.

It is therefore an object of the present invention to provide a mobile radio positioning system, wherein the position of the mobile radio may determined if the mobile radio is positioned close-by to the closest base station.

These and other objects and advantages of the invention will become more fully apparent from the description and claims which follow or may be learned by the practice of the invention.

SUMMARY OF THE INVENTION

The present invention is directed to a method for determining the position of a mobile station within a cellular telephone system. The cellular telephone system has a base station with first, second and third antennas. A first signal is transmitted from the first antenna of the base station to the mobile station, a second signal is transmitted from the second antenna of the base station to the mobile station, and a third signal is transmitted from the third antenna of the base station to the mobile station. The second and third antennas are located proximate to the first antenna at the base station. The first, second and third signals are received at the mobile station at first, second and third relative reception times, respectively. First and second positional measurements are determined based on the first, second and third relative reception times. The position of the mobile station is determined in accordance with the first and second positional measurements.

In accordance with a further aspect, the present invention is directed to a method for determining the position of a mobile station within a cellular telephone system. The cellular telephone system has a base station with first, second and third antennas. The second and third antennas are located proximate to the first antenna at the base station. A voice information signal is transmitted from the mobile station. The voice information signal is received with the first antenna at the base station at a first relative reception time, the voice information signal is received with the second antenna at the base station at a second relative reception time, and the voice information signal is received with the third antenna at the base station at a third relative reception time. First and second positional measurements are determined based on the first, second and third relative reception times. The position of the mobile station is determined in accordance with the first and second positional measurements.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the above-recited and other advantages and objects of the invention are obtained and can be appreciated, a more particular description of the invention briefly described above will be rendered by reference to a specific embodiment thereof which is illustrated in the appended drawings. Understanding that these drawings depict only a typical embodiment of the invention and are not therefore to be considered limiting of its scope, the invention and the presently understood best mode thereof will be described and explained with additional specificity and detail through the use of the accompanying drawings.

FIGS. **1** and **1A** show the operation of a mobile radio positioning system where a mobile station is switched to a positioning channel and power transmissions from the mobile station are temporarily increased in order to allow timing measurements to be made between the mobile station and neighboring base stations, in accordance with a preferred embodiment of the present invention.